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F. C. KEIGHLEY.

THEORETICAL AND PRACTICAL MINE VENTILATION.

BY FREDERICK C. KEIGHLEY.

I have often heard it remarked that ventilation was the most important of all the operations connected with mining, but still more often have I wondered why a work that treats of the ventilation of mines has never yet appeared.

I believe that were I competent to write such a work I would do so, but not considering myself competent I have done the next best thing—that is, ventured to write this paper.

I think that I hear you exclaim, "You are mistaken, there are lots of works on mine ventilation and good ones too. There is Hopton, Atkinson, Fairley and Wilson, who treat on this subject thoroughly, and a host of other authors that treat on it in a general way."

This I admit to be true. They treat on mine ventilation but not of mine ventilation.

These books on ventilation tell you all about mine gases, their deisities, specific gravities, properties, peculiarities and perplexities.

They tell you all about air, its constituents, the laws governing its movements, its specific gravity, density, atomic weight, chemical composition and its life sustaining properties, etc.

Whole chapters are devoted to the demonstration of a coefficient of friction that is sadly deficient in reliability. You wade through whole pages of sectional areas, perimeters, rubbing surfaces, volumes, velocities and sinuosities and finally have all this proved to you by a labyrinth of air columns, squares, square roots, cubes, cube roots and miscellaneous roots, not excepting the root of all evil, money.

Then there is the water gauge, the thermometer, anemometer and barometer, which meter out tables of pressure, tables of temperature, tables of velocities and tables of densities, until the tables are turned against you and you pray for a little ventilation—a breath of pure, sweet air to dissipate the fogs of bewilderment in which you are lost.

Then we have the fans, the furnaces and the instruments of—

torture I was going to say, but I really meant to say displacement machines.

Then we have undercasts, overcasts, splits and subsplits until your head nearly splits.

These are again environed by such an array of doors of wood, doors of canvas, swinging doors, sliding doors, single doors, automatic doors and regulators that you wonder what the regulations are.

Then you have incasts and outcasts, upcasts and downcasts until you are completely downcast.

Next comes the outbyes and inbyes, outtakes and intakes until you are finally taken in with the idea that you know all about ventilation, when the fact is the whole is devoid of ventilation.

After you have reveled in this plethora of facts until you are besotted with knowledge you finally sober up on a philosophic lecture on the atmospheric envelope of the earth and the dreadful consequences that would result if the oxygen got the upper hand of the nitrogen or the nitrogen basely strangled the oxygen.

Now please do not misunderstand me and thus think that I wish to belittle those compilations known and advertised as "Works on Mine Ventilation", for I do not. They are valuable and useful and if taken with caution, in small doses are a wonderful tonic to the mining student and mine manager, but they have been wrongly labeled. They are medicine, not food. They are goods things to know; good things to strengthen the mind; good books for reference, but poor things to ventilate a mine with. A dictionary is a handy thing to refer to, but the learning of it by heart does not make a scholar. So it is with the books I refer to, a man may have them, may study them, yes even thoroughly understand them, and yet never know how to ventilate a mine.

Having, I think, demonstrated that there are no works treating of mine ventilation, I will now follow up the title of my paper, "Theoretical and Practical Mine Ventilation."

Theoretically in ventilating a mine you take into consideration sectional areas, perimeters, rubbing surfaces, pressures, velocities, densities, volumes; the laws governing the movement of air and gases; the laws of diffusion, etc. These again, are determined by the use of formulas made up of co-efficients, squares, square roots, cubes and cube roots.

Practically you rarely or never do any such thing, and I have yet to hear of the man who determined the capacity of the fan he should buy by figuring up the rubbing surfaces of his mine. In practice the probable output of the mine is the fundamental principle that governs the size or capacity of the ventilating appa-

ratus. A given output requires a certain number of men, that certain number of men may burn a certain number of pounds of powder, and a certain number of mules will be required to take away the coal from those men. The men and the mules will require a certain volume of air and the powder smoke will require another volume of air to carry it away and dilute it. Then again the mine may generate black damp or fire damp or perhaps both, and that will take a certain volume of air (in the States of Pennsylvania and Ohio some of these volumes of air are fixed by law), and the aggregate, with an ample margin for contingencies would give the capacity of the ventilating apparatus required. Well we have that fixed and the next question is how to get the air from the ventilating apparatus to the working faces.

Theoretically you make airways of a certain perimeter, area and length.

Practically you do nothing of the kind, for the perimeters and areas of your airways are determined by the thickness of your coal and the nature of the bottom and roof, and the length of the airways are subject to so many changing conditions that you never really know their length.

The books will tell you that air will take the shortest cut, but **in practice** it is just as likely to travel two or three thousand feet out of the way of the short cut as not, and more than once I have seen mine bosses confounded by the paradox of the air returning on what was supposed to be an intake. Right here I think I hear some one say, that is because they do not understand the first principles of ventilation, but to that I will say not necessarily so, for oftentimes in coal mines a mine boss has to ventilate places in defiance of all the laws governing the movement of air and gases.

In all my experience I have never heard of anyone that found it necessary to ascertain the rubbing surface of an airway.

You are told by the books that you must have your splits as nearly uniform as possible. In practice such a thing is never attained or even attempted, for to-day you want air by such a route and to-morrow perhaps by another. One day you want in a certain airway five times, yes perhaps twenty times, the volume you did another day. One day you have men at work in one section and next day perhaps in another and the working forces are continually changing about, requiring a constant change in the supply of air for different sections, so you can see the absurdity of uniformity.

The air currents themselves in a mine are the most changeable of all things and vary every hour of the day. All the splits, doors and regulators in creation will not keep a fixed volume of air

going continuously in any one current. The currents see-saw around from hour to hour and lend and borrow from one another with a freedom unknown even to next-door neighbors.

The ventilation of a mine is a problem that is ever changing and which you have ever got to be changing. To-day checking here and increasing there, to-morrow perhaps cutting off at one place and giving all in another. There are changes of temperature, changes of atmospheric pressure, outbursts of gases, falls of roof and changes of sections of work and all of these changes have to be considered and provided for.

Thorough ventilation is something that has to be learned by long observation, like the piloting of a steamboat on a river. Every mine has its own peculiarities and those peculiarities have to be studied, humored, petted and coerced as the occasion may require. Split air currents are grand things, but they do not make ventilation, they merely facilitate.

Fans, furnaces, steam jets, displacement machines, doors, regulators and overcasts are not the end, but the means to an end. They are to the ventilator what a chest of tools is to the carpenter. The tools help the carpenter but never make the carpenter.

If good square blocks of horse sense could be bought along with books on ventilation and mining we would find more well ventilated mines, and the books themselves better understood and made use of; not stored up in the head. I used to think that people (not excepting myself) were unsuccessful because they did not know enough, to-day I am satisfied that many people are unsuccessful because they know too much. They have converted their heads into band-boxes. They get books on this and books on that, cram their contents promiscuously into their heads until they have destroyed their capacity for reasoning. Something turns up. Well, yes; I read that matter up! Let me see! Figuratively speaking, they run their hand into the band-box and out comes, well everything, but what they want just at that particular times. Like a carpenter ransacking a tool chest in the dark for a gimlet and finding a jack-plane.

None of us make full use of what we know and very few of us understand that our heads are delicate instruments for weighing and gauging accurately what is before us and not beasts of burden, to be loaded down with knowledge that can always be found ready for use in the works of specialists and kept on the shelves of the office or parlor book-case. Books are intended as aids, not loads, and once a man understands this he will not endeavor to carry in his head through life the contents of a hun-

dred or more books, each one of which took years of labor for its priter to produce.

I say get the books by all means, but don't attempt to consume them. Just put them where you can reach them and refer to them when you want them. Weigh them in the balance of reason and take out just what you need. I am aware that I seem to be getting away from my subject but in reality I am trying to fortify the position I have taken.

Now for two practical illustrations and then I am through.

Some time ago I was talking to a friend of mine who is a civil engineer, and he told me of an assistant of his who was one of those people who had converted themselves into a walking encyclopedia. When a newcomer enters the office to wrestle with the pangs of civil war—(pardon me, I mean civil engineering),—the encyclopedia at once strikes terror to the heart of the novice by asking him what he would do if he was called upon to lay out a compound curve. Of course he does not know. This had happened several times until my friend, the civil engineer, got tired of it and one day when the question was propounded to a bright young fellow he spoke up and said the young man would do exactly what I or any other engineer with common sense would do, go to the bookcase and consult a standard work on railroad curves.

Some time ago I was in a certain mine when the mine inspector was questioning the mining boss about his ventilation. The mine inspector said that the ventilation was not what it should be with the amount of air at the foot of the downcast (this was something like two hundred thousand cubic feet per minute). The mine boss replied that no one watched his air currents more than he did. "Why," he says, "I measure the air at seventeen different points every week, and that is more than any man in the district does," and sure enough he did, and had it all nicely tabled, too; but his ventilation was a caulker. I happened to go around with the mine inspector and there was a leak of fifty thousand cubic feet per minute right at the very foot of the downcast shaft; twenty thousand cubic feet per minute going through a stable and the mules all at work; leaks at the overcasts, leaks at the brattices and doors that you could throw a cat through, whilst at the extreme face of the workings there was barely ten thousand cubic feet of air per minute. Yet that man had spent thousands of dollars to ventilate that mine by split air currents. Too much reading and too little observation was the whole difficulty. Why, that man would deem it a joy to spend a half a day explaining to you the beauties of split air currents and figuring square roots, and

he was no college graduate either, but one of your (wrongly named) intensely practical men that had cut his way through a cord of works on mine ventilation and mining.

The first illustration shows that it is always advisable to consult a reliable authority when you can do it, and the second shows that when you have consulted those authorities the work is not done, but only just started and you will have to depend on keen observation, good judgment and common sense to reach success, and above all things it must be remembered that a coal mine is not operated in order that it may be ventilated, but ventilated in order that it may be operated. (Applause.)

PRESIDENT ORTON: Gentlemen, it is a great pity Mr. Keighley could not have been here to read that paper himself; but the next best thing is that Mr. Llewellyn is here to deliver it to us, for I am sure it lost nothing in the reading. It is a very interesting subject, calculated to call out remarks.

MR. LOVE: I do not feel like offering any comment on Mr. Keighley's paper, because he is not present, but in his letter he agrees to grant us that privilege.

Now, as I take it, the paper is a complete answer, or nearly so, to Mr. Kane's paper, and they are very closely in touch. And in speaking of Mr. Kane's paper yesterday, I think some of the members misunderstood my remarks and understood me as condemning theory, which I do not. But I do think that a man depends too much, sometimes, on theory, and sometimes too much on practice. We have had an occurrence during the last year which brought sorrow to this Institute and to the home of one of its members and to the community and company in which he was employed which is to the point. The testimony developed that the accident was solely through too much study. The man had his mind charged with study. He would get up in the morning and spend two hours before going to work in book reading. I do not pretend to say that his reading was all on any one subject, but he was a great reader, and had his mind so charged with study that he did a thing which was not practical, nor is it in accordance with theory, whereby he lost his own life.

I am much taken with Mr. Keighley's paper. I think the author is able to advise us about these things, because he is a

man who is very well versed in theory and also in practice. I had occasion to be at the Mammoth mine that Mr. Keighley had charge of, where there was an explosion of fire damp, or fire damp and dust, causing a loss of one hundred and nine lives and much property. I never had been acquainted with Mr. Keighley, but prior to that time had met him once. However, I came to the conclusion right then, although he had had bad luck, if there was a man in America who understood his business, the business of mine ventilation, that man was Mr. Keighley.

PRESIDENT ORTON: It seems to me that Mr. Keighley has shown us one thing by his paper—or perhaps not by his paper, but by his life—and that is while he advocates the use of not too much theory, etc., he is himself a thorough master of all theories extant, as well as the best practice; and to practice and theory adds the very best of common sense. I think it was pretty clearly shown in the discussion on this subject yesterday that no man can get along without good judgment, whether he has practice or theory, or neither.

MR. KANE: I understood Mr. Love to say that he thinks this paper of Mr. Keighley's a good answer to my paper. Did I understand you correctly, Mr. Love?

MR. LOVE: Yes, sir; I said that.

MR. KANE: With regard to Mr. Keighley himself, I wish to pay him this compliment. I do not know of any man in my experience or whom I have met in my travels, whom I would take to be more or better equipped to ventilate a mine than he is.

I also became acquainted with Mr. Keighley at the time of mammoth disaster at his mine. It so happened that I acted as attorney for the nonce at the coronor's inquest in that case, and had an opportunity of learning the most minute details connected with that catastrophe. While Mr. Keighley was superintendent or manager at that particular mine at that time, I was fully convinced that as far as he was concerned, there was no blame attachable to him whatever. I think he was the unfortunate victim of circumstances. But with regard to his paper, I think Mr. Keighley

has shown considerable talent as a humorist; in fact it is a good deal better than many of Bill Nye's stories that appear in our weekly papers. But Mr. Kieghley has shown that he is a most vulturous reader himself. He could not make references such as he has made, had he not been a most voluminous reader. So I think if a point can be made against Mr. Keighley it is inconsistency in throwing so much cold water on book-reading on the part of other people.

Now, yesterday (and I desire to say now that I would not talk like this if Mr. Keighley had not invited full discussion of his paper) there was a good deal of talk in the discussion which followed my paper on the question of theory and practice, and a question was asked me which I did not perhaps fully answer. As between the practical man and the theoretical man,—that is, the exclusively practical and exclusively theoretical—I will always place my safety and interests in the hands of the practical man. But that is not saying that the practical man comes up to my ideal of a mine boss in the present day. He does not come up to the demands of the present day. It is a foregone conclusion that a man should have good judgment; but on top of that good judgment a man must have practice. But unless he has read books and studied formulae that Mr. Keighley speaks of, and understands something about the laws of the elements he must combat in coal mines at the present day, he is practically worthless. That is the position I take. He would be just as worthless, did he understand all the laws of these elements and could not apply them. It requires practice to be able to apply the knowledge a man has. The only deductions we can draw from that paper is that mines are ventilated in a haphazard way, or something after the plan of those who believe thoroughly in the Monroe doctrine and would have it enforced under any and all circumstances. But Senator Sewell says no, that such action should be taken as at that particular time is deemed necessary for that particular contingency. So in mine ventilation,—if it is attempted to do it regardless to laws and theory, you will find yourself in a box. Even the very men he quotes as having written books, have written what they discovered by actual experience and study in connection

with it; and surely a man cannot be at fault for taking up the discoveries and results of study and experience of other practical men and working according to those laws.

He says that you never measure the area to get a given volume of air. Now, that is not so; the area is measured, I have seen it measured for the purpose of getting a given volume of air. There is a very large margin between the perfect point of ventilation and the killing point, and a mine boss, if he is unscrupulous enough, may range just a few degrees from the killing point up to the perfect point of ventilation, if he so desires, and can almost get those results from any kind of an airway.

In a district where there were about thirty mines within a radius of seven miles, I have seen every one of these mines closed down on a particular day on account of an abnormal lessening of the pressure of the air. The carbonic acid gas, which is peculiar to some mines, and the carbureted hydrogen peculiar to other mines in the district came in such volumes on that day as to drive the men out of the mines, and this within a radius of seven miles had not occurred for fifty years. What effect had that lessening of pressure on the mines or on the people who had the government of these mines? You must remember that in England the mine bosses and mine superintendents do not stay in the mines like they do in this country from morning till night. They had barometers at their homes and when they saw the reduction in the barometers, they made for the mines and took the necessary precautions. Had these men not understood about these pressures and consequent results and stayed at home, the people in the mines would probably have continued work in places where the gas came out half mile beyond the place it usually came, and there might have been a fearful experience. Just a few weeks previous to this there had been a fearful experience, which in my mind and in that of others was caused by just that kind of thing. So I insist on theoretical knowledge being necessary, as well as practical knowledge.

PROFESSOR RAY: There were quite a number of authorities cited in the paper just read, but the best authority has been omitted. The recognized authority to-day, the man who has

treated the subject more scientifically than any of the other writers, and who has written more recently than the others cited, is a Frenchman named Murgue. I would advise every member of the Institute who has the care of ventilation of mines to purchase that book and study it. It comes more nearly meeting the demands of mine ventilation than any author I know of. This author also had a very elaborate paper which he read at the Columbian meeting of the American Institute of Mining Engineers that is published in the last volume of their transactions. It is not a very large book, but there is a great deal of meat in it and it requires some very hard study. The simple or brief statement of his theory is that instead of trying to figure up all the rubbing surface against which the air rubs in passing through the mine, he sums it up by an orifice through a thin plate or partition. An orifice of that kind will offer resistance to the air, and the smaller it is for a given volume, the greater the resistance.

SECRETARY HASELTINE: I think we are under great obligations to Mr. Keighley for that paper, and I regret that there does not seem a greater disposition to discuss it. There seems more meat in it for the mining element of the Institute than any paper which has been presented here for a long time, and he presents in his paper exactly my ideas in regard to the practicability of mine managers and mine superintendents. Mr. Keighley takes the view that a man sitting outside in the office with a certificate of having successfully passed the required examination in his pocket, does not give the mine or mining industry the service that the industry requires. If a man is able to make the calculations and is not able to do the work, he will fall short. A mine boss who knows too much will neglect his mine and rely on his technical knowledge; when on the other hand he would have to depend on his energies and examine his work thoroughly in every particular to see that it is being conducted in a good mechanical manner.

MR. KANE: Take the case of the man mentioned in Mr. Keighley's paper, who had a loss of fifty thousand cubic feet of air at the foot of the downcast shaft. That is taken as militating

against the theoretical man. Now, I wish to ask this question, is the practical man not just as liable to make that mistake as the theoretical man? I hold that the theoretical man is less liable to commit that error than the practical man for this reason. I hold that mental laziness is far greater to overcome than physical laziness. The man who has energy enough to equip his mind with theoretical knowledge of any kind is never going to be laggard when it comes to watching the operation of anything he has in his care. The practical man who has the opportunity of gaining theoretical knowledge and will not exert himself to procure it is more lazy, if I may use that expression, than the man who has spent hours and hours at the most onerous of labor equipping his mind with knowledge; and being less energetic in that respect, he is liable to be less energetic in looking out for leaks.

SECRETARY HASLERTINE: I was basing my remarks on my experience, which has been that the man who relied entirely upon practical knowledge, or almost entirely (I am not talking about the man who cannot read or write, but a man who has a large experience and a moderate amount of education)—that the man who depends on his own experience and not upon mathematical education is always attending to his work in all its details, for he has nothing else to depend on. I think a practical man with a good, fair education and a large amount of common sense is the most desirable man to put on the inside of a mine to take charge of it. Outside the mine, I would advocate having a man with a technical education.

MR. JONES: I want to say, Mr. President, that I endorse most emphatically the paper that has been presented to this convention by Mr. Keighley, and I feel, as one who participated in that discussion on the side I did yesterday, that our ranks have been wonderfully reinforced by such a champion, and feel that we can go forward more confidently that we are correct. Mr. Kane invited our attention to seven mines in a given radius in the old country, where the danger to the miners was made manifest to the superintendent at his home by the falling barometer and he proceeded to notify the miners of the danger. I believe

that every man in that mine knew long before the superintendent and mine boss at home were aware of the danger, the existence of the conditions mentioned, because they were required to deal with those elements in that mine. I do not mean to say that because a man is unable to sign the certificates necessary to send to the chief inspector of Ohio, that that is a special and particular reason why he should be rejected as a mine boss. I only want to say, Mr. Chairman, that if I were compelled to choose between a theoretical and practical man, if I had all the money invested in the mines of Ohio and everywhere else, my investment would be placed in the hands of the practical man every time; because I believe he is better able and more competent to take care of those interests intrusted to him.

MR. LOGAN: I desire very much to learn something about continuous and split air currents. I must say that I admire throughout the substance of Mr. Keighley's paper. I believe firmly in practicability, but also believe in theory. I think the majority of cases cited in the Institute where theoretical men have made mistakes are the exception and not the rule. I believe that Mr. Keighley is right in stating that many blunders are made in putting in downcasts, overcasts, doors and airways—yet, at the same time a man without theory (and I may say that theory comes from practice) will make a mistake in this century if he attempts to ventilate without such knowledge. Therefore, I request that some practical man give us information regarding the ventilation of mines.

MR. PRICE: I enjoy this argument very much: I also enjoyed that paper. I myself never thought it was such a great thing to ventilate a mine. I say that with candor. I always thought with good judgment and attention to business and knowing how to conduct the air, a man was always successful. I am not a highly educated man, never had anything but a common school education; but I do say that if a man uses proper judgment and attends to his business, he will have no trouble in ventilating a mine, but it can only be done by keeping the work close. By having all these things more complicated, it is more trouble to

attend to it. I do not want to be understood, however, as not advocating a higher education. A man may have all the practical experience he can get, but the more education he has with it, gentlemen, the better equipped he is to conduct any kind of business.

(After a few further remarks along the same line, the discussion closed, and on motion of Mr. Kane, seconded by Mr. Jones, the secretary was instructed to communicate to Mr. Keighley the hearty thanks of the Institute for his paper.)

PRESIDENT ORTON: The next paper is on a subject of very great interest in these days, and comes from a gentleman well able to handle his subject—"Mine Wiring. The Distribution of Electricity in Coal Mines," by Charles A. Pratt, E. E., Chicago, Ills.